SEMI-ANNUAL REPORT

JULY 15, 1992

NASA CONTRACT NAS5-31368

MODIS TEAM MEMBER

STEVEN W. RUNNING
UNIVERSITY OF MONTANA

ASSOC. TEAM MEMBERS

E. RAYMOND HUNT and RAMAKRISHNA R. NEMANI

PRE-LAUNCH TASKS PROPOSED IN OUR CONTRACT OF DECEMBER 1991:

We propose, during the pre-EOS phase to: (1) develop, with other MODIS Team Members, a means of discriminating different major biome types with NDVI and other AVHRR-based data. Natural lifeform types of interest are broadleaf and coniferous forests (boreal- temperate-tropical etc discriminated by climate) chaparral- shrubland, grassland. Discrimination will be based on canopy bi- directional reflectance properties, seasonal phenology and surface climate. (2) develop a simple ecosystem process model for each of these biomes, BIOME-BGC based on the logic of the current FOREST- BGC; (3) relate the seasonal trend of weekly composite NDVI to vegetation phenology and temperature limits to develop a satellite defined growing season for vegetation; and (4) define physiologically based energy to mass conversion factors for carbon and water for each biome. Our final core at-launch product will be simplified, completely satellite driven biome specific models for ET and PSN based on this modified dNDVI logic. These algorithms will be in MODISDIS before launch. We will build these biome specific satellite driven algorithms using a family of simple ecosystem process models as calibration models, collectively called BIOME-BGC, and establish coordination with an existing network of ecological study sites in order to test and validate these products. Field datasets will then be available for both BIOME-BGC development and testing, use for algorithm developments of other MODIS Team Members, and ultimately be our first test point for MODIS land vegetation products upon launch. We will use field sites from the National Science Foundation Long-Term

Ecological Research network, and develop Glacier National Park as a major site for intensive validation.

OBJECTIVES:

We have defined the following near-term objectives for the first two years of our MODIS contract based on the long term objectives proposed above.

1. Organization of an EOS ground monitoring network with collaborating U.S. science agencies.

2. Compiling a journal article summarizing the products planned by MODLAND during the EOS era, for distribution throughout the scientific community.

3. As development of the MODIS Surface resistance product, mapping the seasonal changes in surface moisture status over the continental US from NOAA/AVHRR.

4. Develop improved algorithms for estimating LAI from AVHRR data.

5. Implementation of Regional Hydro-Ecological Simulation System (RHESSys) to all of North America.

6. Development of a generalized ecosystem process model, BIOME-BGC, for the simulation of the carbon, water and nitrogen cycles for different biomes.

7. Use BIOME-BGC to estimate continental net primary production (NPP) from AVHRR-NDVI data.

8. Develop advanced logic for landcover classification using carbon cycle simulations from BIOME-BGC.

WORK ACCOMPLISHED:

OBJECTIVE 1: Organization of an EOS ground monitoring network with collaborating U.S. science agencies.

EOS-LTER Discussions

Steve Running attended the annual NSF-LTER site coordinating meeting in Wisconsin in February 26-28. He presented his ideas on EOS-LTER cooperation to the LTER Executive Committee, and then to the overall LTER Coordinating committee, which represents all 17 LTER sites. After the presentation, a vote of interest was unanimous from all site participants. I also met in Washington D.C. with Dr. Jim Edwards of NSF on March 26 to discuss the NSF administrative requirements for participation. The LTER Executive Committee, chaired by Dr. Jerry Franklin met on June 18 and verified interest in this collaboration. Members of the LTER Executive Committee then met with NASA Headquarters administrators Drs Wickland, Murphy and Waring and myself on June 19, to discuss next plans. It was agreed to establish a small ad hoc working group to draft a memorandum of understanding between NASA and NSF on this collaboration. I met with this working group in Seattle, on July 13 and drafted this MOU. We anticipate that this MOU will be signed by both parties by the end of this summer.

BOREAS Proposal

A proposal to the BOREAS project was written on behalf of MODLAND, and mailed on April 22. We propose our involvement in BOREAS to be a full dress rehearsal of our EOS algorithms planned as at-launch core products. Additionally, we plan BOREAS to provide us with a wealth of field data for algorithm testing and validation. We now await the Boreas review and selection process.

IGBP Biospheric Aspects of the Hydrologic Cycle (BAHC) As vice-chair of BAHC, SWRunning has responsibility for developing and executing the science agenda of this core IGBP project. Many of the IGBP science objectives are tightly related to EOS science objectives, and are being executed by many of the same people. At our Science Steering Committee in Berlin, in April 27- 30, plans were made for public exposure of the BAHC science plan in Columbia MD at the ISLSCP meeting, and in November 15-18 in Tolouse, France.

OBJECTIVE 2: Writing a journal article summarizing the products planned by MODLAND during the EOS era.

Material from the MODLAND BOREAS proposal is being used to revise the draft MODLAND paper. A flowchart summarizing the MODLAND product and interrelationships has been drafted (Figure 1).

OBJECTIVE 3: Development of the MODIS Surface resistance product.

A strong negative relationship is generally observed between NDVI and surface temperature at regional scales. The slope of the Ts/NDVI relation is found to co-vary with surface resistance to latent heat transfer from conifer forests in western Montana. Further analysis of this approach revealed that the Ts/NDVI relation is primarily controlled by fraction of vegetation cover and surface moisture status. Vegetation phenology was found to be important in controlling the spatial heterogeneity which is critical for defining the Ts/NDVI relation. To test this approach on a continental scale, we developed an automated approach to define a relation for any given Ts/NDVI scatterplot. Using the EDC 1 km AVHRR data we produced continental scale maps of surface moisture status for the months of June and July 1990 (Figure 2).

OBJECTIVE 4: Develop improved algorithms for estimating LAI from AVHRR data.

We have tested a three channel AVHRR algorithm for improving discrimination of LAI in different biomes (see Figure 3 and Nemani et al 1992). Addition of the mid IR Channel 3 improved the LAI definition for the Glacier National Park scene shown.

OBJECTIVE 5: Implementation of Regional Hydro-Ecological Simulation System (RHESSys) to all of North America.

RHESSys is a data and simulation system that combines remote sensing and GIS as a parameterization scheme with a set of climatological, hydrological and ecological models to compute and map carbon, water and nutrient flux processes at various spatial scales. RHESSys plays a key role in the evaluation of MODIS generated carbon and water fluxes over different biome types and climates.

In order to study how ecosystem processes can be scaled from single tree to continental scales, we implemented RHESSys at the following spatial scales: 1) Watershed (<15 km2, Landsat/TM 30m): Soup Creek, MT, McDonald Creek, MT, HJ Andrews, OR; Coweeta, NC; Kanza Prairie, KS; 2) Regional scale (<500 km2, Landsat/TM 100m): Seeley-Swan Valley, MT (see Figure 4); State of Montana at 1km scale; 3) Continental US at 1 km (work in progress).

OBJECTIVE 6: Development of a generalized ecosystem process model, BIOME-BGC.

1. BIOME-BGC was extensively updated with new variables and algorithms so that biogeochemical cycles of grasslands and broadleaf deciduous forests could be simulated. Moreover, improvements were made to existing algorithms to enhance error handling and error prevention. These changes include a distinction between coarse and fine roots because of differences in respiration rates and litter quality, and incorporation of a starch storage pool to handle autocorrelation of NPP among years (Figure 5). A new algorithm for photosynthesis (based on the work of Farquhar, von Caemmerer and Berry) was incorporated into BIOME-BGC for two reasons: one, the new algorithm can be more easily parameterized from the ecophysiological literature for different ecosystems, and two, simulations with increased atmospheric CO2 would be more realistic (see enclosed paper by Hunt and Running in the Canadian Journal of Remote Sensing). Other new algorithms include having different soil moisture release curves based on soil texture class and different phenologies for fine roots based on soil temperature and moisture. Finally, new program control structures were added to increase the flexibility of the model for different users.

2. We used BIOME-BGC in an analysis of dry matter yield (n), the conversion factor between absorbed photosynthetically active radiation (APAR) and NPP (see enclosed paper by Hunt and Running, IGARSS'92). These analyses are important because NDVI is approximately the fraction of absorbed to incident photosynthetically active radiation, hence APAR may be remotely sensed using NDVI. The analyses compared n for different ecosystems in different climates, different amounts of ecosystem biomass, different soil textures and water hold capacities, different ecophysiological parameters, and the year-to-year changes due to climatic variation.

3. One Masters thesis was finished by Mr. Agus Hidayat comparing water balance and BIOME-BGC simulations with NDVI for a tropical evergreen rainforest in Indonesia.

OBJECTIVE 7: Use BIOME-BGC to estimate continental net primary production (NPP) from AVHRR-NDVI data.

The analyses of n (called dry matter yield after Steve Prince as there is no better term and the terminology is in a state of change) for different ecosystems and climate indicated that climate and morphological variables

(amount of leaves, stems and roots) was more important in determining the value of n than ecophysiological variables. One of the more important findings was the strong dependence of n on the amount of woody biomass (Figure 6). Increased woody biomass increases the amount of carbon lost to maintenance respiration thereby lowering NPP. Thus, one of the more important future tasks for remotely sensing NPP will be the estimation of woody biomass. Another important finding is that the year-to-year variation in the value of n due to year-to-year variation in climate may significant (differences in APAR were accounted for). For the Mission to Planet Earth, much of the variation seen by MODIS may be due to year-to-year variation in climate, BIOME-BGC may be used to separate vegetation's response to global change from this source of variation.
Agus Hidayat found a good correlation between highest-monthly NDVI and simulated monthly water balance or NPP for an evergreen tropical rainforest, thus extending our research into another biome. One of the most interesting findings was that integrated NDVI over a year was negatively correlated with NPP and precipitation. We hypothesized (after Justice et al. 1991) that during the driest year (1987, which had an El Ni$o-caused drought) had less clouds and atmospheric water vapor so AVHRR channel 2 would be higher, thereby increasing NDVI.

OBJECTIVE 8: Develop advanced logic for landcover classification using carbon cycle simulations from BIOME-BGC.

I (SWR) suggested at the ISLSCP Americas meeting some specific carbon cycle variables that may be useful for developing a functional (rather than discriptive) global landcover classification. Among these are leaf area index, specific leaf area, leaf age, photosynthetic capacity and leaf nitrogen concentration. Sensitivity analysis with BIOME-BGC simulations has identified these as the most critical physiological variables for carbon cycle analysis.

Using the ecological principles guiding BIOME-BGC, we can define a small number of lifeforms for use in a general land cover classification. The same lifeforms occur in different climates; for example, grass lifeforms predominate cotton grass-sedge tundra, tall-grass prairies, short-grass steppes and tropical grasslands. Furthermore, conifers occur in boreal, temperate and tropical climates; it is the climate that controls NPP directly and indirectly through natural selection. Initially, three criteria were postulated to define the lifeforms: allocation to woody biomass (grass versus tree), leaf shape (needle versus broadleaf), and leaf longevity (evergreen versus deciduous). The last criterion is for nitrogen cycling because deciduous leaves have higher decomposition rates.

DATA/ANALYSIS/INTERPRETATION:

I don't know what to put here.

ANTICIPATED FUTURE ACTIONS:

<u>EOS Ground Monitoring Network</u>

We (SWR and LTER group) are planning a joint LTER-MODLAND workshop to plan specific datasets for interchange during the EOS period. This workshop will be held before the summer of 1993.
I am also talking with Dr Pete Comaner of the U.S.Park Service Global Change Program on August 25 to explore the prospects of their global change sites contributing to EOS ground monitoring.

<u>MODLAND Paper</u>

Material generated, particularly flowcharts and figures, for the BOREAS proposal are being incorporated into the MODLAND text. New landcover text and BRDF text are planned. Dr. Marv Bauer, Editor of Remote Sensing of Environment, has agreed to publish this paper, upon normal review.

<u>Surface Resistance</u>

1. Determine if EDC bi-weekly composite data can be used for generating the Ts/NDVI relations. What are the consequences of generating the composite AVHRR data based on highest surface temperature instead of highest NDVI?

2. Formulate methodology to normalize the Ts/NDVI relations for local meteorological conditions so that day-to-day and region- to-region relationships can be compared.

<u>RHESSys Simulations</u>

1. Refine the NDVI-LAI relationships for various biomes.

2. Map soil water holding capacities at continental scales using the climate-soil-leaf area hydrologic equilibrium approach. First test will be Montana state map.

3. Complete implementation of RHESSys at 1 km scale for the continental US.

BIOME-BGC Development

1. With the significance of woody biomass for the remotely sensing of NPP with MODIS, I (ERH) am invited to a NASA-sponsored Vegetation/Synthetic Aperture Radar workshop at Pellston, Michigan in August. Microwave radar has the potential but not a demonstrated ability to remotely sense woody biomass.

2. ERH is involved in an international effort sponsored by the Scientific Committee On Problems of the Environment (SCOPE) comparing model predictions of ecosystem response to global climate change. BIOME-BGC for coniferous forests is one of the models being compared. We will meet in Uppsala, Sweden in September 1992 to present our results.

3. Much of my (ERH) research over the next two years will be testing BIOME-BGC for grasslands with the FIFE data set, now available on cd-rom. BIOME-BGC's precursor, FOREST-BGC, has been well validated for coniferous forests, but grasslands are very different. The FIFE data set is ideal for this purpose. Also, I (ERH) am involved in a grassland-ecosystem model comparison with Tim Kittel, William Parton, and David Schimel; the results will be presented in August at the annual Ecological Society of America meeting.

NDVI Based Landcover Definition

An essential precursor to future model development is to settle on a landcover classification logic for MODLAND. Consequently we are scheduling a special MODLAND workshop for Sept 21-23, hosted by SWRunning at Flathead Lake Montana to develop and agree upon this logic.

PROBLEMS/CORRECTIVE ACTIONS:

None

MEETINGS ATTENDED:

MODIS Science Team meeting, April 1992. ERH, RRN IGBP Workshop on Net Primary Production, College Park, MD January 1992. ERH,RRN International Satellite Land Surface Climatology Project Americas meeting, Columbia, MD June 1992. SWR,ERH,RRN IGARSS meeting Houston, TX June 1992. ERH International Geosphere Biosphere Program -Biological Aspects of the Hydrologic Cycle SSC, Berlin, Germany. April 1992 SWR

PUBLICATIONS:

Nemani, R, L. Pierce, S. Running and S. Goward. 1992. Developing satellite derived estimates of surface moisture status. Journal of Applied Meteorology (in press).

Nemani, R, L. Pierce, L. Band and S. Running. 1992. Forest ecosystem processes at the watershed scale: Sensitivity to remotely sensed leaf area index observations. International Journal of Remote Sensing (in press).

Nemani, R, S. Running, L. Band and D. Peterson. Regional Hydro-Ecological Simulation System (RHESSys): An illustration of the integration of ecosystem models in a GIS. In: Integrating GIS and environmental modeling, Eds: M. Goodchild, B. Parks and L. Steyaert, Oxford, London, 1992.

Hunt, E. R., Jr. and S. W. Running, 1992. Simulated dry matter yields for aspen and spruce stands in the North American boreal forest. Canadian Journal of Remote Sensing 16:126-134. Enclosed.

Hunt, E. R., Jr. and S. W. Running, 1992. Effects of climate and lifeform on dry matter yield (n) from simulations using BIOME- BGC. IGARSS'92: International Geoscience and Remote Sensing Symposium, vol. II, pp. 1631-1633. Enclosed.

APPENDIX 1.

PUBLISHED PAPERS:

Hunt, E. R., Jr. and S. W. Running, 1992. Effects of climate and lifeform on dry matter yield (n) from simulations using BIOME- BGC. IGARSS'92: International Geoscience and Remote Sensing Symposium, vol. II, pp. 1631-1633. Enclosed.

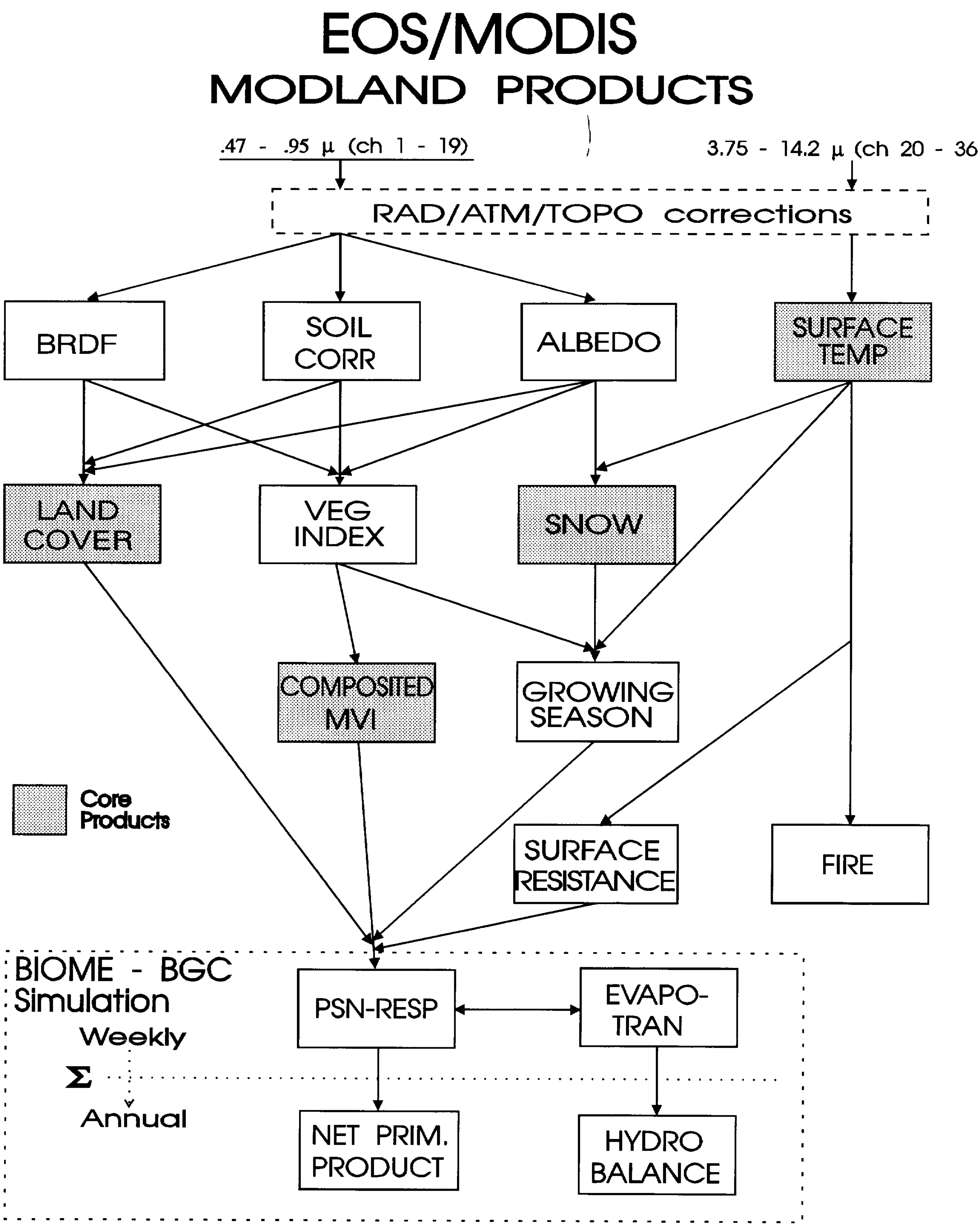
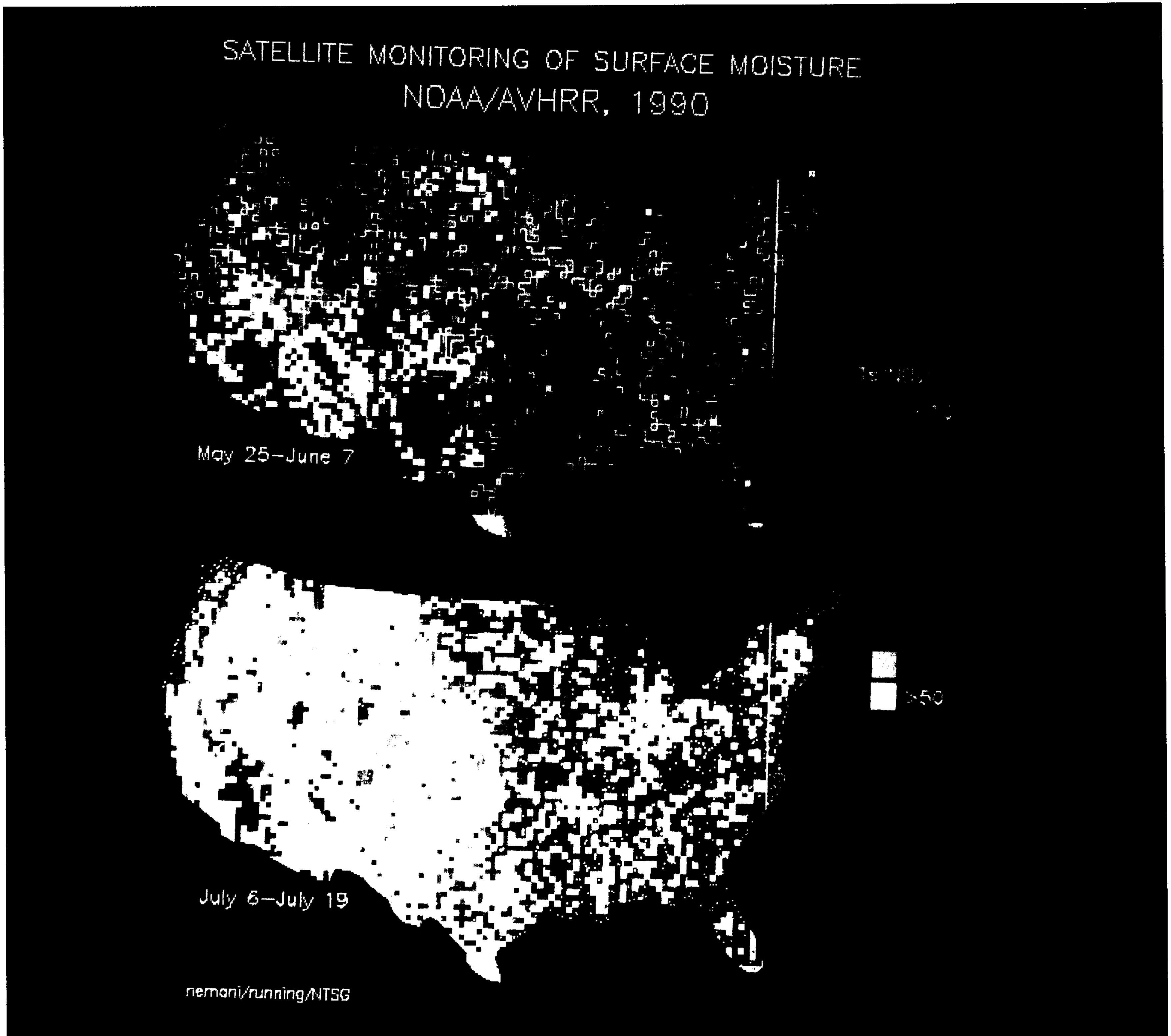

EOS/MODIS
MODLAND PRODUCTS
.47 - .95 μ (ch 1 - 19)
3.75 - 14.2 μ (ch 20 - 36
RAD/ATM/TOPO corrections
BRDF
SOIL CORR
ALBEDO
SURFACE TEMP
LAND COVER
VEG INDEX
SNOW
COMPOSITED MVI
GROWING SEASON
Core Products
SURFACE RESISTANCE
FIRE
BIOME - BGC Simulation
Weekly
Σ
Annual
PSN-RESP
EVAPO-TRAN
NET PRIM. PRODUCT
HYDRO BALANCE

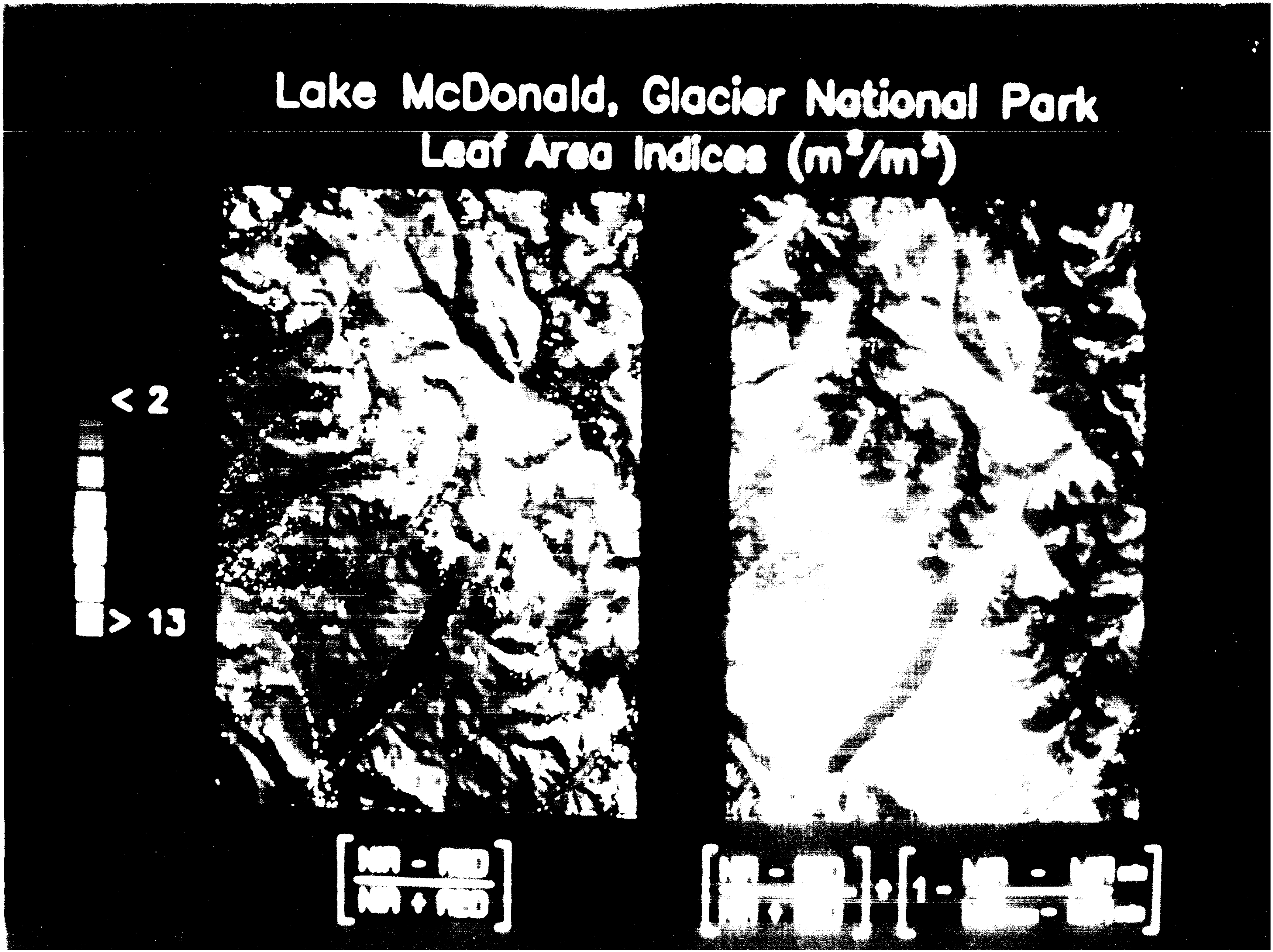
Figure 1

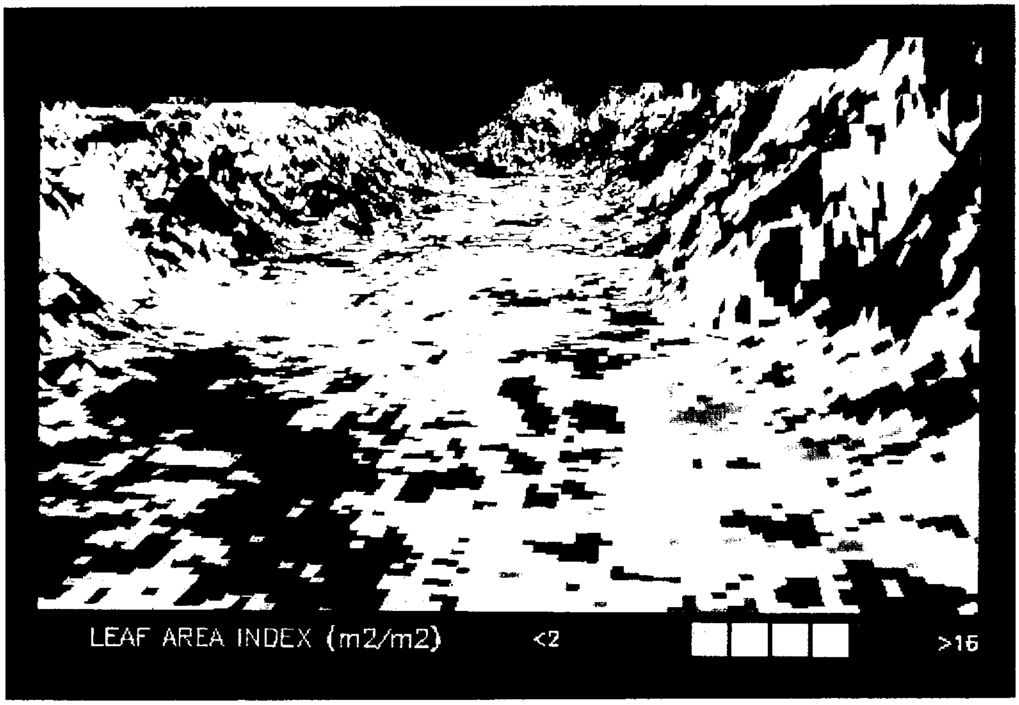
Figure 2



SATELLITE MONITORING OF SURFACE MOISTURE
NOAA/AVHRR, 1990
May 25–June 7
July 6–July 19
>50
nemani/running/NTSG

3


Lake McDonald, Glacier National Park
Leaf Area Indices (m²/m²)
< 2
> 13
NIR - RED
NIR + RED

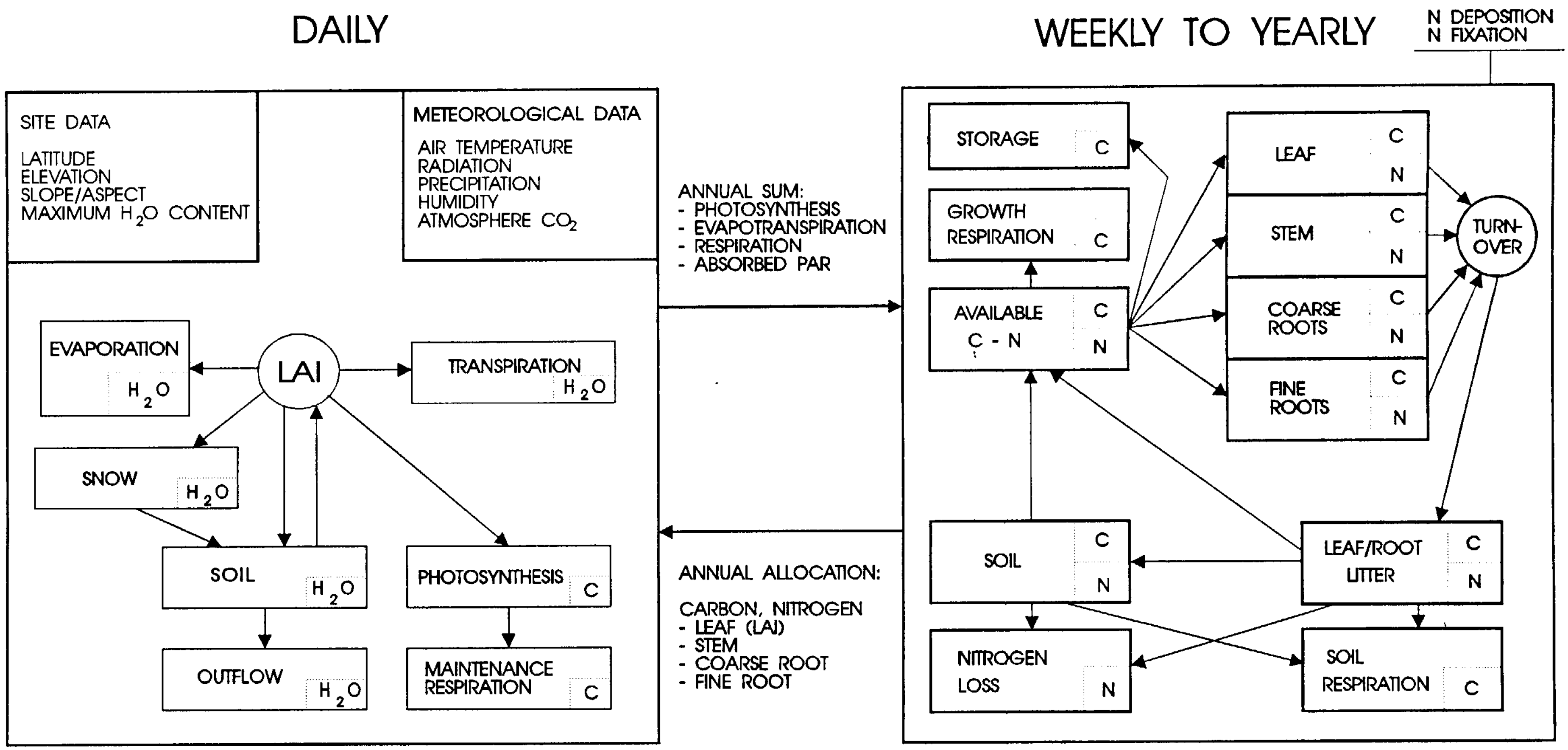

LEAF AREA INDEX (m2/m2)
<2
>15


FOREST EVAPOTRANSPIRATION, SEELEY-SWAN VALLEY, MONTANA
Soup Creek
ET (cm/yr)

Figure 4

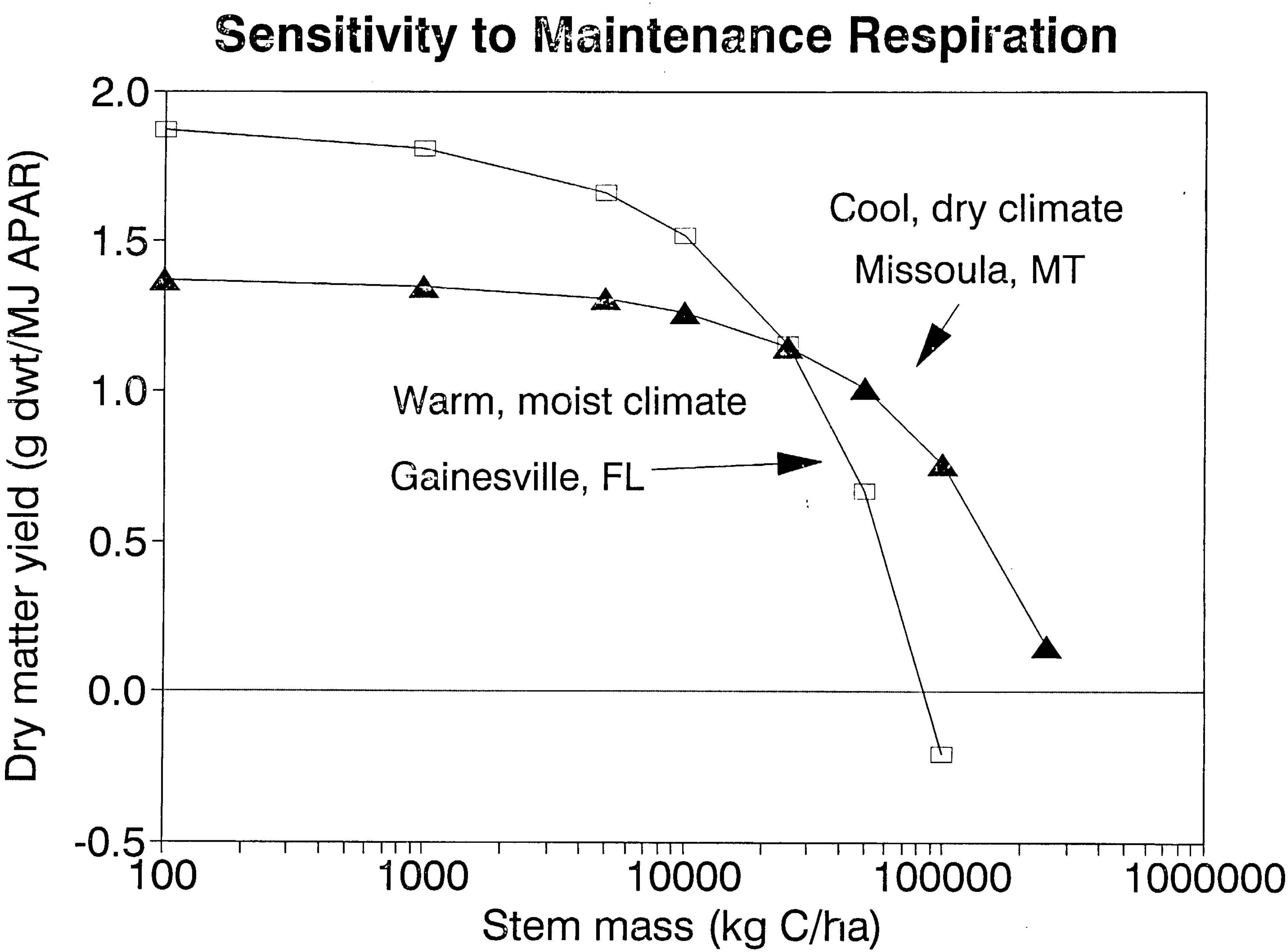
Figure 5

BIOME - BGC



ECOSYSTEM PROCESS MODEL BASED ON
DATA DERIVED BY REMOTE SENSING

Figure 6



Sensitivity to Maintenance Respiration
Cool, dry climate
Missoula, MT
Warm, moist climate
Gainesville, FL
Dry matter yield (g dwt/MJ APAR)
2.0
1.5
1.0
0.5
0.0
-0.5
100
1000
10000
100000
1000000
Stem mass (kg C/ha)